COUNTERACTING MAGNETIC FIELD GENERATOR FOR UNDESIRED AXIAL MAGNETIC FIELD COMPONENT OF A POWER GENERATOR STATOR AND ASSOCIATED METHODS

Field of the Invention

[0001] The present invention relates to the field of power generation and, more particularly, to a power generator and related methods.

Background of the Invention

[0002] A typical power generator includes a shaft and a rotor carried by the shaft. Surrounding the generator rotor is a generator stator. A turbine, such as a gas combustion turbine, a water-driven turbine, or steam-driven turbine rotates the shaft. The generator rotor is supplied DC power typically from an exciter also driven by the shaft. As the generator rotor is turned within the generator stator, electrical power is produced and is delivered to the utility power grid. Rotation of the rotor within the stator may create an undesired axial magnetic field component adjacent opposing ends of the stator. The undesired axial magnetic field component may cause eddy currents that would undesirably heat up the ends of the stator, unless addressed.

[0003] U.S. Patent No. 6,608,419 to Shah et al. discloses a stepped away portion at each end of the stator. To combat the build-up of heat due to axial magnetic flux at each end of the stator core, the inner surface is stepped away from the rotor to increase the distance between the rotor and the stator

core along the ends of the stator core. The increased distance reduces the axial magnetic flux on the ends of the stator core.

[0004] Multiple flux shunts are also disclosed in the Shah et al. patent. The flux shunts are positioned adjacent the stepped away portion of the prior art power generator to attract and redistribute the axial magnetic flux. The flux shunts attract and redistribute the axial magnetic flux by providing a low reluctance path for the undesired axial magnetic flux produced by rotation of the rotor.

[0005] U.S. Patent No. 6,525,444 to Salem et al. discloses a laminate for reducing eddy currents and heating in a stator core to increase generator capacity. The metal lamination package comprises alternate layers of amorphous metal laminate and non-amorphous metal laminate.

[0006] Despite the above disclosed approaches to reduce an undesired axial magnetic field component in a power generator, it is still desirable to provide a more efficient and effective way to reduce, or counteract, the undesired axial magnetic field component at the ends of the stator.

Summary of the Invention

[0007] In view of the foregoing background, it is therefore an object of the present invention to reduce an undesired axial magnetic field component created at the ends of a stator.

[0008] This and other objects, features, and advantages of the present invention are provided by a power generator comprising at least one counteracting magnetic field generator for generating a counteracting magnetic field to counteract an undesired axial magnetic field component. More specifically, the power generator may include a rotor, and a stator surrounding the rotor and having opposing ends. The stator may comprise a stator core and a plurality of windings carried by the stator core creating the undesired axial magnetic field component adjacent the opposing ends of the stator. The counteracting magnetic field generator may be associated with at least one end of the stator for generating a counteracting magnetic field for

counteracting the undesired axial magnetic field component. Accordingly, by counteracting the undesired axial magnetic field component, eddy currents and associated heating may be reduced.

[0009] The counteracting magnetic field generator may comprise a first electrically conductive coil portion positioned for having an electrical current induced therein by the rotor, and a second electrically conductive coil portion positioned adjacent an end of the stator and connected to the first electrically conductive coil portion to receive the electrical current therefrom to generate the counteracting magnetic field. The stator may be spaced from the rotor to define a gap therebetween, and the first electrically conductive coil portion may be positioned in the gap in these embodiments. Alternately, or additionally, the stator core may include a recess therein receiving the first electrically conductive coil portion.

[0010] The windings may comprise end windings extending outwardly beyond respective ends of the stator core, and the second electrically conductive coil portion may be positioned adjacent at least one of the end windings. Relative positioning of the first and second electrically conductive coil portions may provide a desired phase offset for the counteracting magnetic field.

[0011] In other embodiments, the counteracting magnetic field generator may alternately comprise an electrically conductive coil portion adjacent an end of the stator, and a power source connected to the electrically conductive coil portion to generate the counteracting magnetic field. The power generator may further comprise at least one magnetic field sensor, and the power source may comprise a controller for controlling the counteracting magnetic field based upon the at least one magnetic field sensor. The controller may provide a desired phase offset for the counteracting magnetic field.

[0012] In addition to the counteracting magnetic field generator, the stator core may have at least one step at each end thereof, and/or a magnetic

field shunt adjacent each end of the stator. This may further enhance the reduction of the undesired axial magnetic field component.

[0013] A method aspect of the present invention is for counteracting an undesired axial magnetic field component adjacent at least one end of a stator. The method may comprise generating a counteracting magnetic field adjacent the at least one end of the stator to counteract the undesired axial magnetic field component.

Brief Description of the Drawings

[0014] FIG. 1 is schematic block diagram of a power generating apparatus including a counteracting magnetic field generator according to the present invention.

[0015] FIG. 2 is a schematic transverse cross-sectional view of an end portion of the stator of the power generator shown in FIG. 1 illustrating an undesired axial magnetic field component, and the counteracting magnetic field produced by the counteracting magnetic field generator.

[0016] FIG. 3 is a schematic transverse cross-sectional view of the power generator shown in FIG. 1.

[0017] FIG. 4 is a schematic transverse cross-sectional view of the second embodiment of the counteracting magnetic field generator according to the present invention.

[0018] FIG. 5 is a schematic end view of stator end windings of a stator illustrating a second embodiment of the counteracting magnetic field generator according to the present invention.

[0019] FIGS. 6-10 are schematic plan views of an interior surface of the stator showing additional embodiments of electrically conductive coil portions of the counteracting magnetic field generator according to the present invention.

[0020] FIGS. 11-12 are schematic diagrams of two other embodiments of the electrically conductive coils of the counteracting magnetic field generator according to the present invention.

Detailed D scription of the Preferr d Embodiments

[0021] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout, and prime notation is used to indicate similar elements in alternate embodiments.

[0022] Referring initially to FIGS. 1-3, a power generating apparatus **15** including a counteracting magnetic field generator **30** is now described. The power generating apparatus **15** illustratively includes a power generator **20** and an exciter **17** connected thereto. More particularly, the power generator **20** includes a generator rotor **22** and a generator stator **23** surrounding the generator rotor. The generator rotor **22** is mounted to a shaft **24** that is driven by a turbine **26**. The turbine **26** may be a steam turbine, gas turbine, or water turbine as will be appreciated by those skilled in the art. The counteracting magnetic field generator **30** is illustratively positioned adjacent both ends of the stator **23** (FIG. 1) to generate a counteracting magnetic field **99**. The counteracting magnetic field **99** counteracts an undesired axial magnetic field component **97** (FIG. 2) caused by windings of the stator **23** and windings of the rotor **22**. Those skilled in the art will appreciate that the counteracting magnetic field generator **30** may also be positioned adjacent only one end of the stator **23**.

[0023] The stator **23** illustratively has opposing ends, and comprises a stator core **21** having laminations. The stator **23** surrounds the rotor **22**, and an undesired axial magnetic field component **97** may be created adjacent the opposing ends of the stator. The counteracting magnetic field generator **30** is associated with at least one end of the stator **23** for generating a counteracting

magnetic field **99** for counteracting the undesired axial magnetic field component **97**. More particularly, the counteracting magnetic field generator **30** may be positioned at the end of the stator core **21** between the laminations, as will be readily appreciated by those skilled in the art. Accordingly, by counteracting the undesired axial magnetic field component **97**, eddy currents and undesired heating are reduced.

[0024] The stator **23** is illustratively spaced from the rotor **22** to define a gap **29** therebetween, and illustratively comprises a plurality of windings **28**. The counteracting magnetic field generator **30** may illustratively be positioned in the gap **29**. More specifically, the counteracting magnetic field generator **30** illustratively includes first and second electrically conductive coil portions **32, 34**. The first electrically conductive coil portion **32** is positioned for having an electrical current induced therein by the rotor **22**, and the second electrically conductive coil portion **34** is positioned adjacent an end of the stator **23** and connected to the first electrically conductive coil portion to receive the electrical current therefrom to generate the counteracting magnetic field.

[0025] More particularly, the first electrically conductive coil portion **32** is positioned in the gap **29**. The stator core **21** may include a recess **27** therein receiving the first electrically conductive coil portion **32**. The stator core **21** may also have a stepped portion **19** at an end thereof, and may comprise a magnetic field shunt **18** adjacent an end of the stator core **21**. Of course, those skilled in the art will appreciate that the stepped portion **19** and the magnetic field shunt **18** may be positioned adjacent each end of the stator core **21**. The stepped portion **19** and the magnetic field shunt **18** advantageously reduce eddy currents and undesired heating of the power generator **20**.

[0026] Referring now additionally to FIGS. 4-5, a second embodiment of the power generator **20'** is now described. In the second embodiment of the power generator **20'**, the plurality of windings **28'** carried by the stator core **21'** create an undesired axial magnetic field component adjacent the opposing ends of the stator **23'**. The counteracting magnetic field generator **30'** may

illustratively surround the windings **28'**. The counteracting magnetic field generator **30'** illustratively includes a conductive coil portion **35'** adjacent an end of the stator **23'**. The counteracting magnetic field generator **30'** also includes a power source **37'** connected to the electrically conductive coil portion **35'** to generate the counteracting magnetic field.

[0027] The power generator **20'** comprises a magnetic field sensor **40'**, and the power source **37'** comprises a controller **42'** for controlling the counteracting magnetic field based upon the magnetic field sensor. The power source **37'** may provide a desired phase offset for the counteracting magnetic field. The other elements of this embodiment of the power generator **20'** are similar to those of the first embodiment of the power generator **20**, are labeled with prime notation, and require no further discussion herein.

[0028] Referring now additionally to FIGS. 6-10, embodiments of the counteracting magnetic field generator **30** are now described in greater detail. A first embodiment of the first and second electrically conductive coil portions are labeled as above, i.e., **32, 34**. The alternate embodiments of the first and second electrically conductive coil portions **32, 34** are labeled as increasing in numbering by 100 for each alternate embodiment. Further, a graphical illustration is provided if FIGS. 6-10 to note direction, in which Θ represents the peripheral direction, and **Z** represents the axial direction. Relative positioning of the first and second electrically conductive coil portions **32, 34** provide a desired phase offset for the counteracting magnetic field.

[0029] Referring more specifically to FIG. 6, for example, a plurality of first and second electrically conductive coil portions **32, 34** are illustrated. The plurality of first and second electrically conductive coil portions **32, 34** each have a polygonal shape, and are arranged in side-by-side relation along the interior surface of the stator **23**. FIG. 7 illustrates another embodiment of the plurality of first and second electrically conductive coil portions **132, 134.** The plurality of first and second electrically conductive coil portions **132, 134** also have a polygonal shape, but are slightly more slanted than the plurality of first and second electrically conductive coil portions **32, 34** illustrated in FIG. 6.

Further, the plurality of first and second electrically conductive coil portions **132, 134** illustrated in FIG. 7 may be overlapped along the interior surface of the stator **123**.

[0030] In FIG. 8, a pair of first and second electrically conductive coil portions **232, 234** is illustrated, each having opposing polygonally shaped ends, and arranged in side-by-side relation along the interior surface of the stator **223**. In FIG. 9, the first and second electrically conductive coil portions **332, 334** are arranged in an end-to-end linear format along an inner surface of the stator **323**. In FIG. 10, the configuration of the pair of first and second electrically conductive coil portions **432, 434**, is similar to that of the pair of first and second electrically conductive coil portions **232, 234** illustrated in FIG. 8, and are positioned along a lower portion of the interior surface of the stator **423**.

[0031] Referring now additionally to FIGS. 11-12, further embodiments of the first and second electrically conductive coil portions **532, 534** and **632, 634** are now described in greater detail. In FIG. 11, the arrow **89** indicates the main stator core flux. Accordingly, the first and second electrically conductive coil portions **532, 534** are arranged in a loop configuration having polygonally shaped portions. In FIG. 12, an opposing main stator core flux **89** is illustrated. Accordingly, a cross-over point **91** joins the first and second electrically conductive coil portions **632, 634**. In FIGS. 11 and 12, a graphical illustration of direction is provided in which Θ represents the peripheral direction, **Z** represents the axial direction, and **R** represents the radial direction.

[0032] A method aspect of the present invention is for counteracting an undesired axial magnetic field component adjacent at least one end of a stator **23**. The method may comprise generating a counteracting magnetic field adjacent the at least one end of the stator **23** to counteract the undesired axial magnetic field component.

[0033] Many modifications and other embodiments of the invention will come to the mind of one skilled in the art having the benefit of the teachings

presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the invention is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the appended claims.